PROGRESS TOWARDS PATIENT-SPECIFIC COMPUTATIONAL MODELING OF BALLOON ANGIOPLASTY USING MAGNETIC RESONANCE IMAGING

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Balloon angioplasty is a well-established interventional procedure which aims at reducing the severity of atherosclerotic stenoses. It is the most frequently used therapeutical intervention world wide and attracts great and steadily growing medical, economic and scientific interest. A total of 1,069,000 angioplasty procedures (including 601,000 coronary angioplasty procedures) were performed in 1999 in the United States alone [1]. The knowledge that balloon angioplasty is a mechanical solution for a clinical problem implies the necessity for a detailed understanding of the biomechanics and mechanobiology of the types of soft tissues and calcifications involved. It is exactly this understanding that is needed to improve such procedures, which often fail due to restenosis (about 40% within six months at the coronary site).

The presented research deals with the development of a layer-specific three-dimensional computational model for the simulation of balloon angioplasty. The aim is to predict the patient-specific mechanical response of human stenotic arterial walls by considering different procedural parameters such as diameter ratio (balloon to artery), balloon length, inflation pressure, stent type etc. Geometrical data of the plaque architecture is the basis for the three-dimensional computational model and is obtained from **M**agnetic **R**esonance **I**maging (MRI), which is the most promising noninvasive techniques for obtaining accurate geometrical data.

The presented study is a continuation of the research previously reported in [2] (which built in turn on the pilot study [3]) with the incorporation of some important enhancements such as a smoothing technique for contact surfaces of arbitrary mesh topology in 3D, which is required to account for the interaction of balloon, stent and arterial wall. The proposed smoothing technique presents a strategy to parameterize contact surfaces of arbitrary mesh topology with at least C^1-continuity for both quadrilateral and triangle-based meshes. The use of subdivision surfaces avoids non-physical pressure jumps for contact interactions. Refined methods are developed to analyse the mechanical environment in form of, for example, the stress distribution; stent geometries are altered in order to optimise certain target quantities. Another important enhancement is the use of a Linux Cluster at Graz University of Technology, which consists of 24 nodes and one master connected with an internal 300 GB RAID-System together with an external 1TB fileserver. The performance of the system is about 14Gflops and allows high performance computing necessary to solve this type of nonlinear boundary-value problems. The present numerical study also incorporates mesh refinement with respect to the (original) reference geometry and provides appropriate error analyses.

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References

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